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INFORMATION PROCESSING OF DOT MATRIX DISPLAYS.(U)

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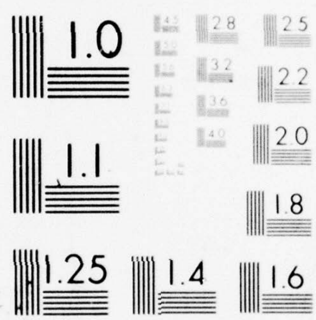

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INFORMATION PROCESSING OF DOT MATRIX DISPLAYS

CREW SYSTEMS INTEGRATION BRANCH
FLIGHT CONTROL DIVISION

OCTOBER 1976

TECHNICAL REPORT AFFDL-TR-76-82
FINAL TECHNICAL REPORT FOR PERIOD 1 JUNE 1974 - 1 MARCH 1975

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AIR FORCE FLIGHT DYNAMICS LABORATORY
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The light emitting diode (LED) display technology provides the display designer with many solutions as well as problems in his design task. The present studies were designed to assess the performance impact of symbologies composed of discrete elements relative to more conventional continuous symbologies. In an attempt to examine information processing of various components of behavior--such as information input, central processing and output--three different tasks were selected. A two-or-four alternative choice reaction time task demonstrated an ability to measure a difference between punctate and continuous information, and suggested

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that the difference is reduced with increased task complexity. A memory search task demonstrated the importance of symbology compatibility and a display search task revealed equal search efficiencies for punctate and continuous alphanumerics. Additional areas of investigation are discussed.

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FOREWORD

This report presents the results of three studies conducted between October 1974 and February 1975 which were sponsored by the Multimode Matrix Display Advanced Development Program Office of the Flight Control Division to establish the acceptability of light emitting diode (LED) dot matrix displays from a performance standpoint. They were designed to supplement other human factors studies, all attempting to establish an information data base to provide display design guidelines.

Thanks are due to Dr. Terry Riley, Bunker Ramo Corporation, for his suggestions and assistance throughout this entire program and to Mmes. C. Cantrell and D. Lewis for their efforts in the preparation and editing of this document.

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SECTION I
INTRODUCTION

As the fields of computer science and electrical engineering develop and mature, those engaged in behavioral research find themselves with increasingly precise measurement and analysis tools as well as certain problems related specifically to technological advances. One such problem is the replacement of visual display technologies such as newspaper print and the cathode ray tube which use symbologies and images which are or appear to be continuous in nature with punctate or dot matrix information presented by a variety of advanced visual displays. This capability was generated by advances in solid state technologies such as semiconductor and large-scale integration and associated software which has caused the word "digital" to become commonplace in the display designers vocabulary.

This drive toward digital systems has not suffered from the lack of a compatible digital display as evidenced by the long list of such displays: plasma, flat panel cathode ray tube, light emitting diode (LED), liquid crystal and others. In the face of so many alternatives, the display designer must be able to determine which technology best suits his needs, not only from a strictly economic standpoint but also from a display legibility and acceptability standpoint. Economic and engineering tradeoffs are typically clearcut while problems of human perception and information processing are more confounded. For example, does the good contrast feature of a liquid crystal display under high ambient illumination compensate for its poor viewing-angle characteristics? Such questions are indeed difficult to answer and indeed even more basic questions remain unanswered. If one were to query a design handbook for standards to apply to dot matrix symbologies, few would be found. Even seemingly simple questions concerning the required character size required for certain viewing conditions become complex in the light of results of a study by Groves (1973) demonstrating that dot matrix (LED) alphanumerics appear 150% larger than continuous counterparts. Above visual threshold, larger, dimmer dots or elements are superior to smaller, more intense dots (Ellis, Burnell, Wharf and Hawkings, 1974). These issues are simply not addressed and, thus, handbook standards are useful for continuous display technologies but not for punctate ones.

This paper covers three experiments designed to demonstrate the ability to measure differences in human cognitive processing capability using dot matrix and continuous alphabetics and to illustrate, using several laboratory tasks, how such differences are manifested. Eventually such information processing analyses should contribute to the establishment of concrete design guides and handbook standards.

SECTION II
EXPERIMENT I

To establish an ability to discriminate between processing of dot matrix versus continuous alphabetics, a two- and four-choice reaction time task was used. This simple task was selected to reduce experimentally induced error and, thus, maximize the probability of obtaining a difference. We predicted that any difference would be manifested as faster processing of continuous alphabetics. Reasons for this difference could be due to some cognitive activity such as perception or memory as affected by familiarity or practice. Experiment II examined the obtained difference in greater detail.

METHOD

A 2 X 2 design reflected the factorial combination of Number of alternatives (2 or 4) and Symbol type (dot matrix or continuous). Symbol type was manipulated within subjects, and each of two groups of 12 subjects experienced either two or four alternatives.

Procedure

Each subject was seated in a dimly lighted sound-attenuated room equipped with a ground-glass screen, a response panel and intercom. Subjects in the two-alternative group were given two letters to memorize and told that these two letters would be presented randomly across 75 trials (each letter occurring on approximately half of the trials). With the onset of each letter the subjects' task was to press a microswitch which corresponded to the letter. Each switch was labeled with the appropriate letter. The response was to be made as quickly and accurately as possible. Subjects in the four-alternative group were given four letters and responded using one of four microswitches. These subjects always used the index and middle finger of each hand and rested these fingers on the switches. Half of the subjects in the two-alternative group used the index and middle fingers on the preferred hand while half used the nonpreferred hand.

Each stimulus letter was presented for 2 seconds followed by a 4.5-second delay interval. There were 4 blocks of 75 trials with 3-minute rests between blocks. The four blocks were completed in a 1-hour session.

Subjects

The subjects were 24 students from local universities who responded to an advertisement. Each was paid for his participation. All subjects had 20/20 or 20/20-corrected vision.

Stimuli

Eight letters of the alphabet were selected to be the population from which either two- or four-letter alternative sets were chosen-A, D, H, I, Q, U, Y and Z. These letters were selected as acoustically and visually neutral (Chase and Posner, 1965). Each of the eight was used equally often and were combined to form 12 two-letter sets (AU, QY, HZ, HQ, AY, DI, IU, DZ, YZ, AH, IQ and DU) and 12 four-letter sets (ADUZ, HIQY, AHIZ, DHQZ, ADQY, AIQU, HIUY, DUYZ, ADIU, HQYZ, DIYZ and AHQY). The white on black stimuli were back-projected on a ground-glass screen and subtended one degree visual angle both horizontally and vertically. The punctate characters were approximately 30% active area relative to the continuous characters but were subjectively equated for overall or average brightness during the photographic process. The character font was Flanders and the punctate characters were constructed so as to be as close as possible to the continuous characters in all aspects of size and shape. The Flanders font was used because the stroke characters were easily adapted to dot-matrix configuration. A 20 X 20 matrix of dots was used to construct the punctate characters. When each character was projected on the screen, the 20 X 20 matrix closely approximated a 64 dot-per-inch resolution.

Apparatus

Two Kodak random-access RA-960 projectors were used with electronically controlled shutters to present the stimuli and to control exposure durations. The subjects' response to the onset of each stimulus was

monitored for speed by a millisecond timer and for accuracy by the experimenter. The response panel consisted of eight microswitches of which only two or four were used, depending on the number of alternatives.

RESULTS AND DISCUSSIONS

The results were based on mean reaction times, excluding errors, reaction times over one second and machine failures. An analysis of errors revealed a significant difference only between two and four alternatives. The positive correlation between percent errors and reaction times indicates that subsequent analyses of the reaction times (Table 1) are valid and not attributable to a speed/accuracy tradeoff.

TABLE 1

ANALYSIS OF VARIANCE EXPERIMENT I

Source	SS	df	MS	F	p
Number of Alternatives (A)	60350.08	1	60350.08	10.75	.01
Symbol Type (S)	363.00	1	363.00	3.75	N.S.
Subjects X A	123495.80	22	5613.45		
A X S	616.33	1	616.33	6.37	.05
Subjects X A X S	2128.67	22	96.76		

Reaction times averaged across the 12 subjects in each group are illustrated in Figure 1. Though there is not a significant main effect due to continuous versus punctate letters ($F=3.75$, $p>.05$), there is an interaction between Stimulus type and Number of alternatives. ($F=10.7$, $p<.01$). The nature of this interaction indicates a superiority of continuous letters at the lower level of uncertainty and a virtual absence of such a difference at the higher level. Thus, under conditions of very little uncertainty (two alternatives), the subject apparently chooses to or has time to process information about the visual nature of the stimulus. That is, the physical nature of the input is relevant and

improves or degrades processing as a function of its visual properties. Punctate characters are certainly less familiar and also convey less information for any given stimulus area. Note, however, that any difference seems to disappear as the number of alternative response choices increases. The increase in uncertainty coupled with instructions to respond as quickly and accurately as possible may be responsible for the convergence seen in Figure 1. The subject may choose to ignore the visual punctate information, thus, making it irrelevant. Because the maximum RT is only 502 msec, a ceiling effect is unlikely.

Such a pattern of results is encouraging. It reveals a difference between punctate and continuous symbologies and demonstrates that such a difference is measurable. Further, the difference declines with a level of uncertainty which is certainly lower than would be found in a cockpit environment. Thus, the use of dot matrix symbologies in flight control displays appears superficially to be feasible. At least there should be little performance difference between punctate and the more conventional continuous displays.

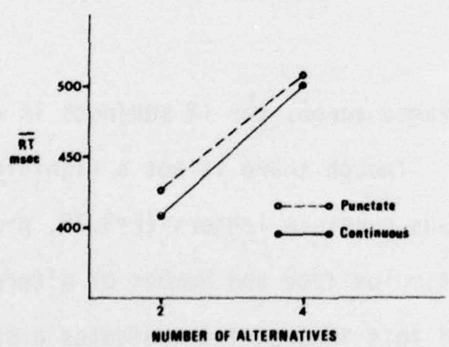

Figure 1. Stimulus Type X Number of Alternatives

SECTION III
EXPERIMENT II

There are several possible behavioral models one could use for assistance in the understanding of human factors studies of dot matrix displays. Decision theoretic, pattern recognition and physiological models are but a few. One that includes a separation of component behaviors such as encoding or information registration, memory operations and response selection is the information processing approach as shown in Figure 2.

Sternberg (1966) introduced a memory comparison reaction-time task which has successfully been used to separate and analyze such components--formerly assigned to a mystical "blackbox." His subjects were presented with a small set of items to be remembered (usually one through eight) called a memory set. After the subject spent several seconds memorizing this set, it was then followed by a probe item which was either a member of the memory set or it was not.

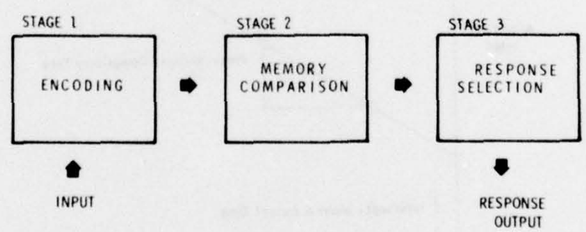

Figure 2. Information Processing Model

If the probe item did match any memory set item, the appropriate response was a positive or "Yes" response usually by means of a button press. A non-match was indicated by a negative or "No" response.

Sternberg (1967, 1969) and many others have demonstrated that average reaction times measured from the onset of the probe item to the onset of the response is a positive linearly increasing function of the number of items in memory as illustrated in Figure 3. The slope of this equation reflects only those changes due to increasing the number of items stored in memory and has been interpreted to indicate the rate of search through memory (or Stage 2 in the information processing model). The intercept includes the remaining stages which include encoding and response selection processes (or Stages 1 and 3 in the information processing model).

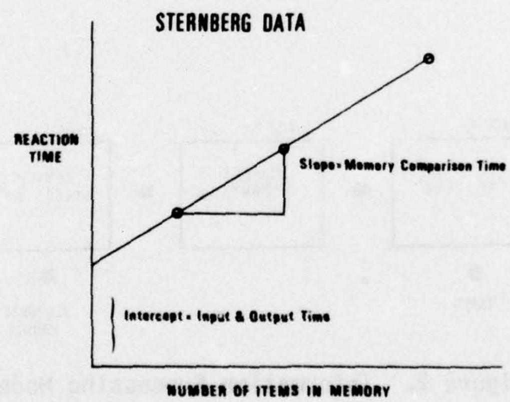

Figure 3

It is not necessary that the information stored in memory be in the same format as the probe item. Examples of dissimilar formats used include: faces and names (Tversky, 1969), faces and descriptions (Nielsen and Smith, 1973), uppercase and lowercase alphabetic characters (Peters, 1974) and auditory and visual modality (Chase and Calfee, 1969). The data from an experiment by Chase and Calfee (1969) using visual and auditory modality items illustrates a pattern of results indicative of 1) slower overall responses to visual probe items as seen in the intercept difference and 2) faster memory search for compatible memory set/probe combinations as seen in the slope differences (Figure 4). These differences can be interpreted as a recording of all those items in memory into a format that allows comparison with the probe item when it is in a different format. A recording of the single probe item would need to be accomplished only once to make all comparisons and, thus,

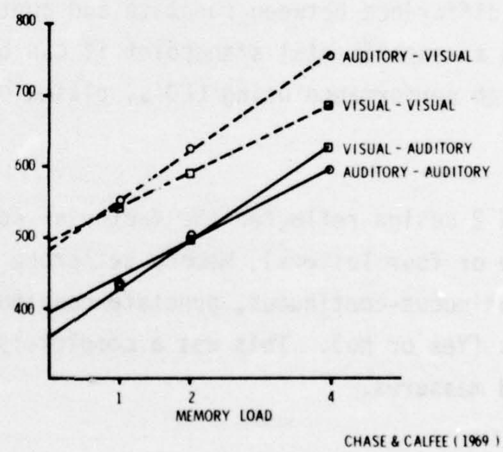

Figure 4

an intercept difference would occur--a result not substantiated by the literature (Swanson, Johnson and Briggs, 1972). It seems inefficient to recode all memory items when a recoding of the single probe would serve to make compatible all items for memory comparison but it may be that the probe item is difficult to recode while it is still present in its original form on the screen in front of the subject.

Experiment II used continuous and punctate alphabetic characters both stored in memory and as probe items. The purpose was to determine whether the format specific information (that is, continuous versus punctate) would be stored in memory or whether this visual information would be lost and replaced by a completely verbal or abstract code which does not differentiate between the stimulus dimensions. Also, if visual information is stored, what is the effect of using the relatively unfamiliar dot format? Does it effect the input of information (as reflected by an intercept difference) or memory comparison (as reflected by a slope difference)? Designers of advanced displays using any dot matrix technology must know how their presentation mode will affect the observer's performance and though a difference between punctate and continuous symbology may be exciting from an experimental standpoint it can be disturbing when hoping to sustain high performance using LED's, plasma or liquid crystal displays.

METHOD

A 3 X 4 X 2 design reflected the factorial combination of Memory load (M = one, two or four letters), Memory set/probe combinations (continuous-punctate, continuous-continuous, punctate-continuous, or punctate-punctate) and Responses (Yes or No). This was a completely within-subjects design with repeated measures.

PROCEDURE

Each recognition trial began with the presentation of one, two or four items which were either all punctate or all continuous. The memory set size did not change for a block of 156 trials. Blocks with different size memory loads were counterbalanced across subjects to reduce order effects. On each trial each set of items was presented for 2.0 seconds

and followed by a probe item of 2.0 seconds duration after a 1.0 second interstimulus interval. The subject's response was recorded as well as the time from the onset of the probe to the onset of the response. Half of the subjects pressed a microswitch with their left index finger to respond to a match and with their right index finger to respond to a non-match. The remaining subject's finger assignments were reversed. The intertrial interval was 4.0 seconds and a total of 156 trials was given for each memory load. These trials were equally divided among the four memory set/probe combinations and the two possible responses, thus, across the 18 subjects, each data point in the results is based on approximately 700 responses. Two one-hour sessions were required to complete the experiment for each subject.

SUBJECTS

The subjects were 18 students from local universities who responded to an advertisement. Each was paid for his participation. All subjects had 20/20 or 20/20 corrected vision and none had participated in Experiment I.

STIMULI

The white on black stimuli were identical to those used in Experiment I. The presentation of the memory sets was visual and simultaneous. For M = 1, the letter was in the upper left corner of a 2 X 2 cell matrix. The remaining cells were unfilled. For M = 2, the upper 2 cells contained the letters and all 4 cells contained letters for the M = 4 condition.

APPARATUS

The apparatus used was identical to that used in Experiment I.

RESULTS AND DISCUSSION

The results are based on mean reaction times and which excluded errors, reaction times over one second and machine failures. Error rates of 2.8, 3.5 and 4.4% for memory loads of one, two and four respectively, suggest that the speed-accuracy tradeoff cannot account for the increase in reaction time with memory load and that subsequent analyses are valid.

Analysis of non-match reaction times suggested no coherent picture and, thus, only match reaction times are used in the following analyses (Table 2). Results collapsed across memory set composition in a plot of punctate and continuous probe reaction time as a function of memory load reveal that when the nature of the memory set is eliminated, there is virtually no difference between responses to these types of symbologies (Figure 5). This, of course, indicates that there is no real difference or that attempts to equate punctate and continuous fonts for brightness and shape were successful. Such variables which classically effect encoding did not produce any intercept difference. Thus, to achieve equal information processing performance punctate smybology must appear as bright as continuous symbology which means increased measured intensity. The increase in intensity required probably being a function of dot size/ dot spacing relationships which effect apparent brightness.

When memory set composition is illustrated while collapsing across probe type, a slope difference is observed (Figure 6). Thus, when continuous letters are stored in memory the search through these items is faster than when punctate items are stored, regardless of the nature of the probe. This memory comparison rate difference may be due to the relative unfamiliarity of the punctate letters. Continuous symbologies appear to facilitate memory search, but the questionable intercept effect suggests that there is little encoding or information registration difference observed. Certainly, the fact that the intercept constant for punctate letters is lower than for continuous characters (438 versus 454 msec) should not be interpreted as a facilitation due to the punctate nature of the letters. Note that Chase and Calfee (1969) also found such crossover of equations (Figure 4). Perhaps the solution lies in appropriate scaling.

The emerging picture so far is one of the importance of the nature of those items stored in memory and a de-emphasis of the nature of the probe items. However, the relationship between the two must be considered and is critical. A significant interation between Memory load and Memory set/ probe combination illustrates that recoding into like formats is required.

TABLE 2

ANALYSIS OF VARIANCE EXPERIMENT II

Source	SS	df	MS	F	p
Memory Set (M)	.4234	2	.2117	17.46	<.01
Subjects (S)	.8437	17	.0496		
Conditions (C)	.0081	3	.0027	4.71	<.01
M X S	.4122	34	.0121		
M X C	.0181	6	.0031	4.36	<.01
S X C	.0293	51	.0006		
M X S X C	.0705	102	.0007		

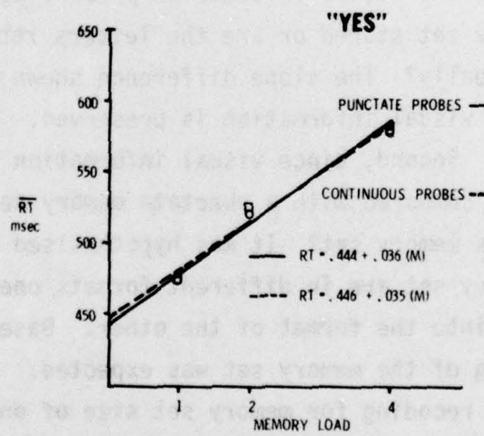

Figure 5. Probe Composition Effect

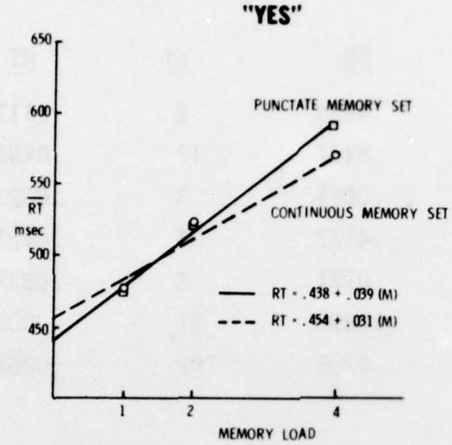

Figure 6. Memory Set Composition Effect

Two questions arise. First, is information preserving the visual characteristics of the memory set stored or are the letters represented verbally or at least non-visually? The slope difference shown earlier (Figure 6) indicates that this visual information is preserved. These data will be supplemented later. Second, since visual information is stored, can a continuous probe be compared with a punctate memory set as efficiently as with a continuous memory set? It was hypothesised that whenever the probe item and memory set are in different formats one or the other would need to be recoded into the format of the other. Based on logic discussed earlier, a recording of the memory set was expected. If this occurs, then there should be one recoding for memory set size of one, two recordings for memory set size of two, and four recordings for memory set size of four. Thus, a slope change was predicted.

An examination of the two combinations where punctate information is stored in memory (Figure 7) shows that the compatible condition, where punctate information is both stored in memory and presented as the probe item, yields a faster comparison process. The recoding of the

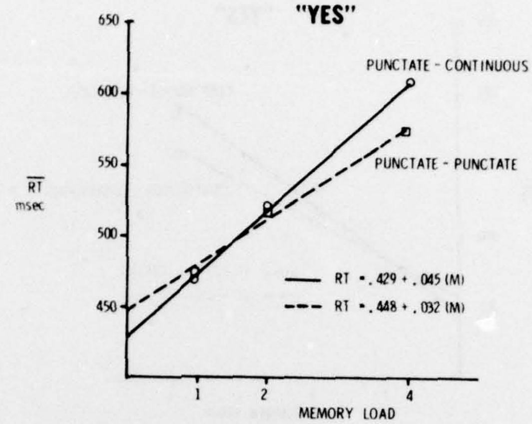

Figure 7. Compatibility with Probe Memory Set

punctate memory items, when a continuous probe is presented, is reflected in the increased slope (45 versus 32 msec). Thus, not only are items stored visually but the relatively unfamiliar punctate symbologies are stored in such a fashion as to preserve this information. A similiar picture emerges when the continuous memory/set continuous probe and continuous memory set/punctate probe equations are examined (Figure 8). We find that, again, the compatible continuous-continuous combination is processed more efficiently and that recoding is evident when memory set and probe item are in different formats. Note that the subjects seem to be able to encode either type of information equally effectively into whichever format is appropriate to make the comparison (i.e., the slope differences are 13 and 11 msec in Figures 7 and 8).

What are the practical implications of such results? Note that the particular recognition task selected, though seemingly a very laboratory-oriented task, is in fact one which involves components of behavior found in much more complex tasks and certainly found in flying tasks

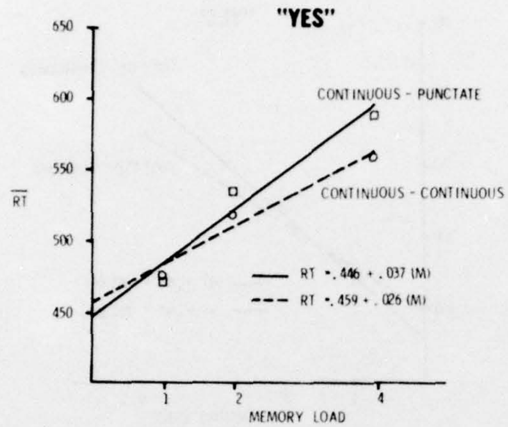

Figure 8. Compatibility with Continuous Memory Set

involving display reading. The processes of information encoding, memory comparison and output processes are found in nearly every operational visual task. What then can be said about dot matrix information presentation based on this study? To equate encoding performance, punctate information must be of equal subjective brightness--achieved through intensity increases or dot size/dot spacing relationship changes. Even if the encoding performance is equated, observers can and do maintain visual information in memory leading to differential memory search efficiencies. While the differences in this experiment are small (approximately 12 msec), it must be remembered that pilots have far more than one, two or four possible alternatives and memory searches can be quite extensive and, thus, time consuming. A practical implication of these results is that if an observer must compare two items presented at different times, such as occurs when monitoring navigation information, the information should be presented in the same format each time.

SECTION IV
EXPERIMENT III

A component behavior not partialed out by the methodology used in Experiment II is visual search. The importance of such a task is illustrated by an early history of eye movement studies in simulated and actual aircraft by Fitts and his co-workers. (Fitts, Jones and Milton, 1949; Jones, Milton and Fitts, 1949; Jones, Milton and Fitts, 1950; and Milton, Jones and Fitts, 1949). The role of the pilot in today's advanced aircraft increasingly emphasizes monitoring activities while de-emphasizing aircraft control and guidance. Compounded with an increasingly bewildering array of visual (and auditory) displays,the visual monitoring or scanning burden has become critical. The purpose of this experiment was not to improve scanning patterns, dwell times or number of fixations by using dot matrix displays, but rather to find out whether in a simple laboratory visual search task minimizing the importance of eye movement, there is any performance decrement observed using dot matrix relative to continuous alphabetic symbols. To this end,visual searches through lists of 1, 2 or 4 alphabetics to find an appropriate target were employed.

METHOD

A 3 X 4 X 2 design reflected the factorial combination of Display set (D = one, two or four letters), Display set/target combination (continuous-punctate, continuous-continuous, punctate-continuous and punctate-punctate) and Responses (Yes and No). This was a completely within-subjects design with repeated measures.

PROCEDURE

The procedure and timing were idential to Experiment II except that each search trial began with the visual presentation of one target item which could be either punctate or continuous. The display to be searched followed presentation of the target and was composed of 1, 2 or 4 alphabet characters--all punctate or all continuous. Note that this simply reverses the sequence of Experiment II. The subject's task was to determine whether or not the target item was present in the display set. All

letters appeared equally often and when the target was in the display array it occurred equally often in each possible position.

Half of the subjects used their preferred hand for the match response and their non-preferred hand for the non-match response. The remaining subjects' finger assignments were reversed.

SUBJECTS

The subjects were 12 university students who responded to an advertisement. Each was paid for his participation and all had 20/20 or 20/20 corrected vision. These subjects had been in neither Experiment I nor II.

STIMULI AND APPARATUS

The stimuli and apparatus were identical to those used in Experiment II.

RESULTS AND DISCUSSION

The results are based on mean reaction times which excluded errors and times over 1 second. As in Experiment II the positive correlation between errors and display search time eliminates a speed/accuracy trade-off explanation for changes in search time. Error rates for D = 1, 2 and 4 were 4.2, 6.4 and 11.1% respectively.

An analysis of variance (Table 3) reveals that there is a significant difference ($F = 9.74$, $p < .01$) between "Yes" and "No" responses. The fact that the match responses were faster than the non-match responses (581 versus 606 msec) may be indicative simply of differential response output time and not necessarily a self-terminating search. The lack of interation between Responses and Display set size ($F = 1.93$) certainly does not indicate a self-terminating search through the display--while an exhaustive search cannot be ruled out.

TABLE 3

ANALYSIS OF VARIANCE EXPERIMENT III

Source	SS	df	MS	F	p
Display Set Size (D)	.7605	2	.3803	12.20	<.01
Conditions (C)	.0004	3	.0001	.11	N.S.
Responses (R)	.0445	1	.0445	9.74	<.01
Subjects (S)	2.2228	11	.2021		
S X D	.6857	22	.0312		
S X C	.0375	33	.0011		
D X C	.0130	6	.0022	1.58	N.S.
S X R	.0503	11	.0046		
D X R	.0080	2	.0040	1.93	N.S.
C X R	.0063	3	.0021	1.37	N.S.
S X D X C	.0904	66	.0014		
S X C X R	.0458	22	.0021		
S X C X R	.0506	33	.0015		
D X C X R	.0086	6	.0014	.94	N.S.
S X D X C X R	.0999	66	.0015		

The main effect of display set size was significant (F = 12.20, p<.01) and is illustrated in Figure 9.

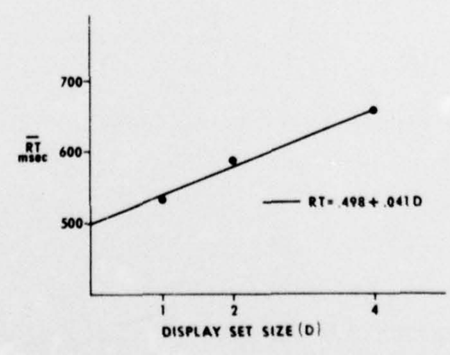

Figure 9. Display Search Speed

Though increased reaction time with increased display set size is a common finding (Teichner and Krebs, 1974) it is noteable that Display set size did not interact with Display set/target combination ($F = 1.58$). This indicates that search times did not differ as a function of the constitution of the target (punctate or continuous) or of the display set (punctate or continuous). Unlike a memory search (Experiment II), an incompatibility between target and display set composition in a visual search task does not degrade search processes. No second or higher order interactions were significant.

SECTION V
GENERAL DISCUSSION

There are many possible methodological approaches to improve display quality, study display characteristics or assess display utility. The approach taken in this report was to select several tasks that load components of an observer's information processing system and to monitor changes in task performance as a function of the load. The tasks selected reflect those components that are important not only in laboratory-oriented situations but also in the performance of daily activities. The job of using displays to pilot an aircraft undoubtedly involves visual search, input or encoding, central processing and output processes - all components examined in the present paper.

The first experiement was intended to demonstrate that a measurable difference between punctate and continuous symbology could be observed. The results revealing a difference were expected - the nature of the difference was not. We did not anticipate that with four altenatives there would be no difference between the symbologies. The fact that the interaction was statistically significant suggested that experimental imprecision was not the cause of the lack of difference. More likely, a strategy difference existed between the two conditions. The relatively simple two-alternative condition allowed the subjects to process the visual information (punctate or continuous) while the relatively more complex four-alternative condition was sufficiently demanding to disallow such unnecessary processing.

Thus, apparently in situations where the visual nature of a verbal message is irrelevant, subjects can determine whether or not they deal with such information. When task complexity reaches a level where dealing with such information might potentially degrade performance, the observer can elect not to process that information. In a flying environment, even the most simple tasks are sufficiently difficult to preclude the luxury of unnecessary information processing. We would expect then that symbol identification in a real-world situation would be executed with equal efficiency for punctate and continuous symbologies.

In Experiment I, there was an emphasis on symbol identification or input of information. What differences might result from a more complex task emphasizing decision making (or central processing) as well as information input? Experiment II addressed this issue. Figures 6 and 8 reveal the importance of the nature of those items stored in memory relative to those items used to probe memory. This fact is clarified by the logic discussed earlier explaining why memory items and not probes are recoded. One may argue that recoding into like formats is never necessary for memory comparison and that the slope differences (Figures 7 and 8) are due simply to an increased comparison time because of the dissimilar formats (punctate vs. continuous). This explanation explains little and ignores evidence suggesting that observers do have image generation or recoding capability (Posner, Eichelman, Boies and Taylor, 1969). Thus, apparently upon presentation of a probe item, subjects either proceed with the memory comparison if probe and memory items are in the same format as those items in memory, or they recode those items in memory in a serial fashion if they are in a format incompatible with the probe item.

Because of the small absolute differences found in this experiment, it would be tempting to attribute little practical significance to the results. However, several factors must be considered. First, the differences between the punctate and continuous symbols were purposely minimized; and in another (real life) situation with greater physical differences, the recoding times might be increased. Second, the overall-levels of uncertainty involved, relative to the complex activities associated with aircraft display reading, are low.

Experiment II shows that use of continuous characters facilitates information processing performance, especially when such information is stored in memory. However, compatibility of presented and stored information can substantially reduce any performace difference; and techniques to increase intensity or active area can also serve to equate obtained performance. Also, a reduction in the familiarity differential through increased practice with and use of punctate information may further reduce any differences. Vast experience with continuous alphabetics in

newspapers and television, for example, has certainly provided observers with biases. This is an area in need of further research.

Visual search behavior, studied in Experiment III, was not unlike that found in many previous studies using a variety of continuous symbols and alphanumerics. The difference obtained (increase RT with increase in display set size) attests to the adequacy of the experimental methodology. The lack of interaction of Display set size and Display set/target combinations suggests that there is no facilitation due to target - display format compatibility and that visual searches, unlike memory searches are not affected by the nature of the visual information. Presumably, whatever visual features used in the comparison of a target (in memory) with a displayed item (on a screen) are different than those features used in the comparison of a group of memory items with a probe (on the screen). Why this is so is a matter for future study. A contributing factor may be an issue discussed earlier. When the visual nature of a stimulus is irrelevant, an observer can elect not to deal with it and the probability of this is increased by increased task complexity. The visual task certainly appeared more difficult than the memory search task (visual search grand mean = 594 msec and memory search grand mean = 528 msec) reflecting greater task complexity. This, coupled with the possibility that stimuli in the environment (on the screen) are more difficult to recode, might explain why observers use different features when performing visual search as opposed to memory search tasks.

The results of the present experiments indicate that though differences in the processing of punctate and continuous symbologies do exist, those differences are concentrated in memorial operations and can be reduced with consideration of format compatibility, as well as equation of overall intensity. Effects of familiarity and practice may also contribute to the difference and should be further studied.

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